RELATÓRIO FINAL		NÚMERO DO DOCUMENTO **CT-RE-003-2022**
NOME DO PROJETO – SUBPROJETO - ATIVIDADE **MapSãoFrancisco – Lower Stretch Francisco River** **Mapping populations in flood zones risk** **Multi purpose dynamic research trimaran – prototype**		DATA DA REALIZAÇÃO **13de julho de 2022**
CONVÊNIO – PATROCÍNIO – APOIO INSTITUCIONAL **Cooperação HOT – Humanitarian OpenStreetMap Team; UFAL – Universidade Federal de Alagoas; InfoSãoFrancisco**		NO. DO CONTRATO **Sem contrato**
REALIZADOR (ES) **Sociedade Socioambiental do Baixo São Francisco – Canoa de Tolda**		
RESPONSÁVEL **Carlos Eduardo Ribeiro Junior**		CARGO – FUNÇÃO **Coordinator/Developer**
ETAPA (S): **MPDT 001 construction and evaluation**	SITUAÇÃO: **Finished** **Last rev. 13/07/2022**	USO: **MapSãoFrancisco/partners**
NOTA:		VERSÃO Português - **English**

1. **Background**

With the continuation of the activities of the Baixo São Francisco subproject, from MapSãoFrancisco, the HOT – Humanitarian OpenStreetMap Team sent to Brazil a training team that was in the region between June 27th and July 08, 2022.

With a HOT coordinator/manager for the project, Marina Aragão and the hydrologists hired for the technical and educational support of MapSãoFrancisco, Sten Schurer and Miguel Trejo, the HOT team developed field activities aimed at training in:

a) dry bathymetry;

b) Wet bathymetry;

c) Obtaining images with aerial scanning with a drone;

d) Flow measurements with the OpenRiverCam system;

e) Use of systems (programs) for the development of the activities listed above.

All activities aimed at generating data and information that, in turn, will allow for the establishment of risk zones for flooding in the Lower São Francisco, allowing, finally, the general objective of the project, which is the collaborative mapping of populations in such locations.

All the processes carried out in the first region object of the field activities followed the precept of MapSãoFrancisco and its cooperative members of transfer of alternative advanced technologies, citizens, in order to result in inclusion and social empowerment, through access to accurate information, in short, citizen science for decision-making by society.

2. New wet bathymetry systems

In the specific case of wet bathymetry, a new high-precision, easily accessible, low-cost sonar system was tested, with the potential to generate accurate analysis, hassle-free data transfer, and the production of easy-to-view graphs. All operated from mobile devices like cell phones. The Deeper Pro+2 echo probe was selected as equipment, originally developed for recreational activities.

The sonar, extremely easy to use, basically consists of a spherical unit (65 mm in diameter), which contains inside the sensors (depth and scanner), a GPS (capable of receiving signals from the GPS, GLONASS, Galileo , BeiDou, QZSS), an information transfer system via Wi-Fi to a mobile device (within a range of up to 100m) and a battery (Li-Ion, 3.7V rechargeable, 950 mAh) capable of up to nine hours of use. The depth measurement capability, according to the manufacturer, is up to 100 m. All controls and settings are carried out by the dedicated Deep application installed on the mobile phone.

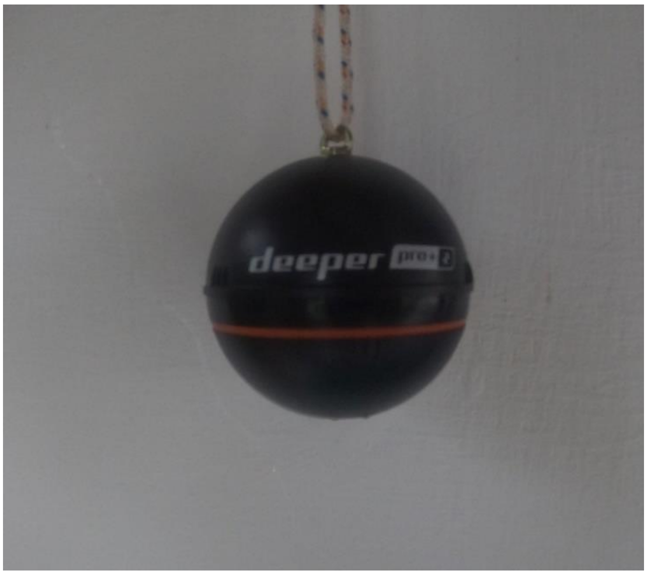

Figure 1 - Deeper Pro+2 unit. The red line corresponds to the equipment's waterline.

The Deeper unit is floating being activated when in direct contact with the water (immediately starts its scans, measurements and transmissions) and must be moved over the zone(s) in which the bathymetric knowledge is intended and the relief of the submerged soil.

For the transmission of the signal with the information to the receiving device, it is necessary that the upper part of the unit is, for most of the time, out of the water. Such a condition implies speed restriction/towing configuration of the rig unit according to its design, with a fishing line or thin cable. Also sea conditions affect the rig's standard operating procedure.

Since the region covered by MapSãoFrancisco basically consists of extensive ADIs – Areas of Interest along the São Francisco River, a large river, it is necessary that the bathymetry activity, whatever the process, be carried out in a timely manner, or the project will be unfeasible in terms of cost and time of completion. Due to the nature of the risk situations applied to a large population in Baixo São Francisco, it is necessary to urgently produce information from the numerous prospections that include bathymetry.

3. **A support vessel for the bathymetry system (and others)**

It became evident, due to the vast region to be scanned, of the need to implement other operating procedures with the Deeper Pro+2 probe in order to carry out soundings at higher speeds than expected, and even in more adverse sea conditions. As a solution, it was proposed to build, on the first day of field activities, a prototype of a small vessel that would receive the equipment(s) and be towed by one of the speedboats.

The best equipment model was defined as a trimaran, a vessel with three hulls: a central one, which receives the payload and two floats.

The choice of a trimaran as a support vessel for the rig is due to:

a) Greater transverse stability of the vessel;
b) Greater longitudinal stability of the vessel;
c) Possibility of higher speed operations due to better (lower) hydrodynamic drag of the hull;
d) Better passage of the trimaran in small surface waves and those produced by the mother vessel.
e) Wide-width base that would allow the adoption of other equipment, if necessary, for other uses.

It is important to note that the objective/goal of the construction and use of the trimaran prototype would be the validation of the concept of the use of the Deeper Pro+2 probe (until then an experimental device in the activities of MapSãoFrancisco) embedded in an equipment that allowed the optimization of the use of its interesting technical characteristics.

With the MapSãoFrancisco team (Canoa de Tolda, InfoSãoFrancisco, UFAL – Federal University of Alagoas and HOT) in the village of Ilha do Ferro, an isolated location in the high backlands of Alagoas, the prototype of the trimaran should be built in a few hours (or a few minutes) with inexpensive materials available locally. To this end, 30 mm thick polystyrene foam boards for school use were obtained, specific glue for this material, 20 mm diameter PVC tubes, 3 mm polyester cables.

Based on our many years of experience in the design, construction and navigation of multihull vessels, a quick line plan was drawn up for the central hulls and floats, which would be constructed with two foam laminations in order to reach the final thickness of 60 mm.

The entire constructive process of the prototype of the trimarã followed the collaborative, collective line, like all the other activities of the training and the MapSãoFrancisco initiative. All people from the team participated in all stages of the construction/operation of the trimaran.

The trimaran prototype was designed with the main (provisional) characteristics:

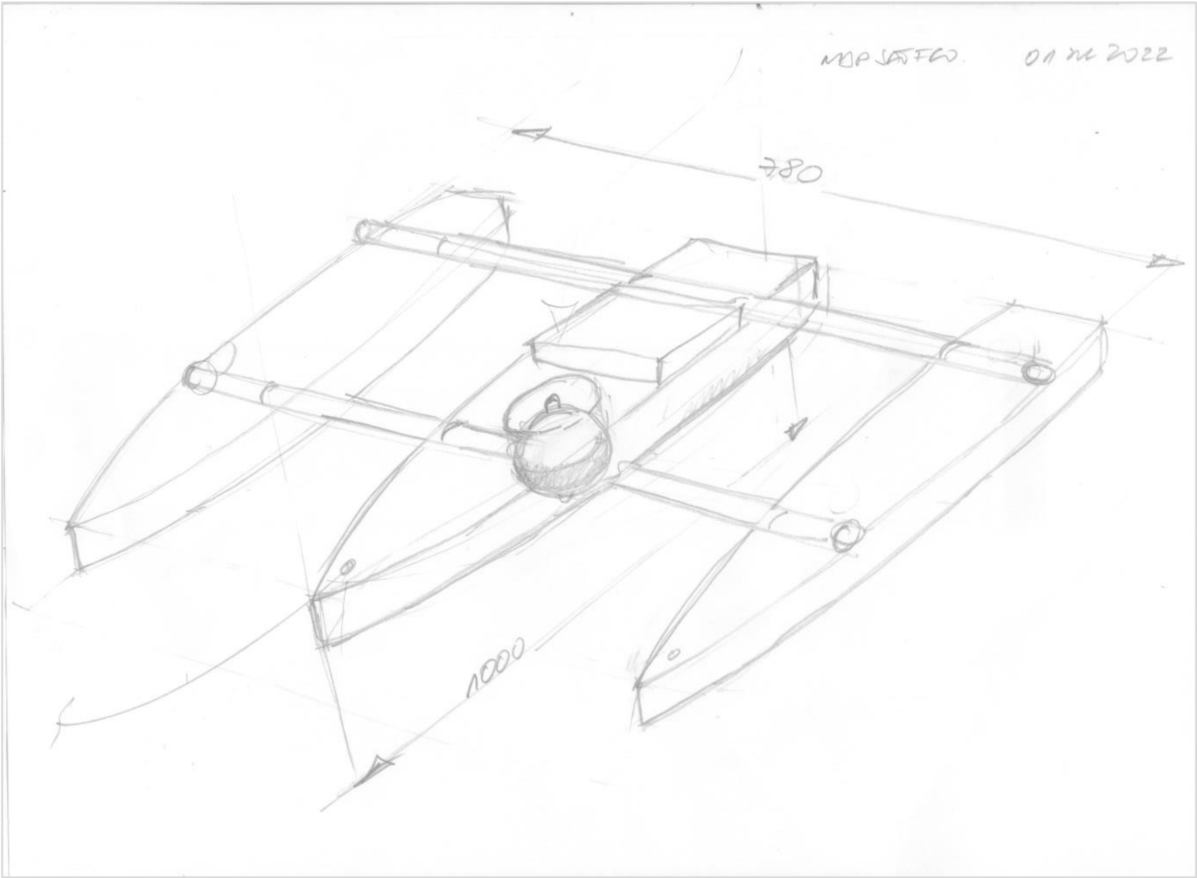

Figure 2 - Sketch of the concept of the trimaran that made its construction possible

LOA - Length overall – 1000 mm
BOA – Beam overall –780 mm
Height – 60 mm
Main hull beam -– 240 mm
Floats beam – 150 mm

The trimaran was designed in a few minutes, taking as a reference the shape of the Deeper Pro+2 unit, its waterline and the free space in the upper area for the emission of data signals[1].

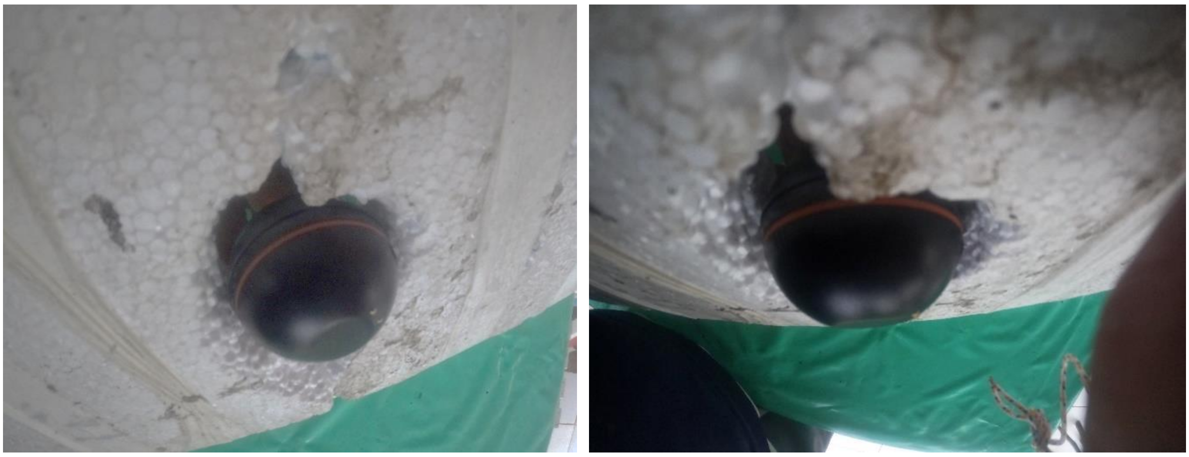

Figure 3a e 2b - Probe installed at the bottom of the trimaran. The small metallic dots are the depth and scan sensors.

Thus, the Deeper Pro+2 was installed in a kind of "pit" amidships of the vessel. As there was still no knowledge about the effectiveness of the sonar GPS, a laminated base was made aft of the probe well for the application of a generic GPS RTK antenna developed by HOT and used in dry and wet bathymetry. The idea would be to compare Deeper's GPS signals with RTK.

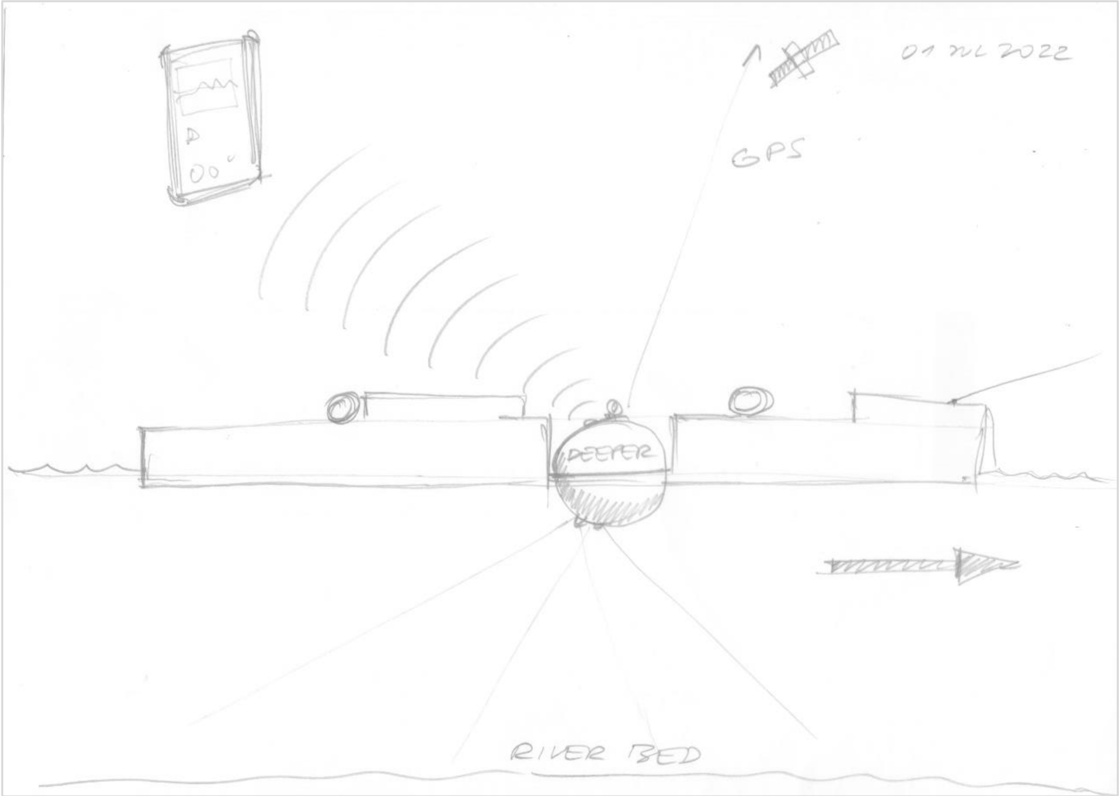

Figure 4 - Basic concept of Deeper's trimaran operation

With no possibility of using fasteners such as screws, all trimaran elements (PVC hulls and arms) were assembled and moored with thin cables (3mm), including the probe mooring.

To tow the trimaran, a simple and lightweight collapsible structure was built to be attached to the edges of the boat with cables. This structure was made with PVC tubes for irrigation with a diameter of 50 mm. Support bases were made with plywood and epoxy in order to prevent the structure from rolling.

The towing structure is still in the development phase and should undergo adjustments together with the tests of the next prototype of the trimaran.

4. Navigation tests and data acquisition

On June 30, the first sea trials were carried out with the multipurpose trimaran. With the towing structure installed on one of the work boats, the trimaran was attached by its bow to the boat's port side.

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[1] The shapes of the hulls were idealized with reference to the inadequate structural quality of the foam used, which forced the realization of lashings of adhesive tapes on the central hulls and floats to avoid the breakdown of the lamination.

The probe was inserted into its well, secured with a safety cable. Due to the lack of knowledge of the quality of the Deeper Pro+2's sonar, a GPS RTK antenna was also installed just behind and as close as possible to the probe, for the elaboration of a second map with the route taken (for superposition and comparison with the map prepared by the probe's GPS).

The sweeping zone in the São Francisco river compartment between the Ilha do Ferro village and the Belmonte island was used as a test area. Tracks were followed (with bathymetry data generation, riverbed scanning and both GPS – Deeper and RTK) of river sections and longitudinal sections along the North and South banks.

Weather conditions were favourable, with light easterly winds, small ripples, and river flow

During the tests, there was some initial difficulty in maintaining the probe at its waterline level inside its well: the device jumped in the midst of the swirling water in that space. The problem was solved by installing a transverse cable over it, limiting its vertical movement.

The reception of sweeping, bathymetry and GPS signals was generally very good.

To improve heading stability, a cable was launched from the stern of the port float towards the stern of the speedboat, in order to control a certain tendency to move away from the trimaran.

There was also a tendency towards bowing of the bows, due to the still reduced thickness of the sections ahead of the bow arm, making evident the lack of buoyancy in these sections.

In the specific case of sea and wind conditions, the potential for operation with speeds of up to about 6 knots (over water) was observed, performing the sweeps with the current. There is clearly a possibility of improvement in the overall performance of the scan, with a considerably larger area being covered in a shorter time.

We cannot forget that the prototype used did not have hydrodynamic shapes compatible with the operation, which had a considerable influence on the maximum operating speed limit. There was a risk of disintegration of the structure, due to the characteristics of the foam used.

The expectation is that with the next prototype, with elaborate hydrodynamic shapes, it will be possible to carry out sweeps with even higher speeds.

Overall, the concept was considered approved for operations with the Deeper Pro+2 probe. Being properly stabilized in its base/support, the probe performed its role with complete satisfaction.

Regarding the data, there was a difference in precision between the probe's GPS and the RTK (variation of up to 2.00 m between track axes) that would not justify, at least for now, the installation of the most accurate model[2].

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[2] The final decision on whether or not to install the GPS RTK will be subject to the mission profile and the precision needed to obtain data from it.

For the second round of tests, an extra 30 mm lamination was made on the bows of the central hull and of the floats, which immediately contributed to the better behavior of the trimaran in the water. With excess flotation, a small increase in operating speed was possible.

Still in the second battery of tests, unfortunately, the central hull ruptured, in the areas adjacent to the rig well, which was expected due to the insufficient structural qualities of the foam, as already mentioned.

The rupture of the central hull also caused a fracture of the bow of one of the floats, which forced us to abandon the tests.

In order to complete the drilling, extra lamination was carried out in the fractured areas, new lashings with adhesive tapes, which would allow the final work to be carried out on July 7th. The final bathymetries in the southern channel of the island of Belmonte were performed only with the central hull manually maintained in a stable position.

5. Conclusion

The concept of the multi-purpose dynamic trimaran can be considered as effective, which guarantees its approved status.

The analysis of the operations with the prototype made allowed to delineate the necessary characteristics for the development of the next experimental model.

Some points to consider when developing the 002 prototype:

a) The Deeper probe must be installed in a base/case with a firm, precise fit, which keeps it in the conditions determined by the manufacturer: sensors in the water, unimpeded transmission zone;
b) The sensor fitting system should allow the use of other equipment and not only the Deeper probe, guaranteeing other uses for the trimaran – something like a fitting plug, with a specific plug for each type of sensor;
c) The fluctuation in the bow sections must be significantly increased;
d) The structure for fixing the hulls (arms), always easy to assemble and dismantle, must be carried out in light aluminum tubes for greater rigidity of the set;
e) Fixing points (handles) must be provided on the bows of the floats for mounting a halter-type trailer, with a small adjustment system, which provides greater stability to the trimaran;
f) Provision of attachment points (handles) at the stern of the floats for mounting the stabilization cable system;
g) Flat platform on the central hull for the eventual installation of other accessories.

Operating from a stable base like the trimaran, the Deeper Pro+2 probe shows that it can be an important piece of equipment in carrying out bathymetry and scans, with good accuracy and low cost.

There is also the possibility of evolving the equipment to other forms of use, including autonomous, a trend that should not be discarded in the future.

6. Next steps

As the activities of MapSãoFrancisco are currently the main testing environment for the concept of the dynamic multi-use trimaran, numerous wet bathymetry surveys will be required in the next steps.

Thus, it will be necessary to use a new trimaran that, based on the results obtained with the simplified prototype, will consist of a new generation model, with hull shapes closer to those of the final version.

One of the objectives for the trimarã is its construction/implantation anywhere in the world with projects similar to those of MapSãoFrancisco where the following should be considered:

a) Use of local materials (wood, foam block);
b) Simple construction processes (shape manually or with numerical control machines);
c) Low material and production costs;
d) Variable load capacity according to the uses (drilling, ADCP, water quality, electric motor installation - trimaran operating as a drone) of each project;
e) Easy assembly and disassembly of equipment for transportation in remote regions;
f) Resistance and simple and inexpensive maintenance;

From the above considerations, the construction process of the next prototype is being evaluated between three modalities:

1- Hull and floats shaped in high density foam and then laminated with fiberglass;
2- Wood/epoxy strip plank;
3- Strip plank of divinycell/epoxy and glass strips;
4- Marine plywood.

The design of the evolved forms of the new prototype must have as parameters the real payload of the trimaran according to its use: drilling, water analysis, autonomous use (which will require an electric motor, battery and control system), a possible *generic* ADCP.

Reserva Mato da Onça, 14 de julho de 2022

Carlos Eduardo Ribeiro Junior

The following is the photographic record of the development and testing of the 001 prototype of the multi-purpose dynamic trimaran:

Figure 5 – Prototype design

Figure 6 - Idem

Figure 7 – Preparing hulls patterns

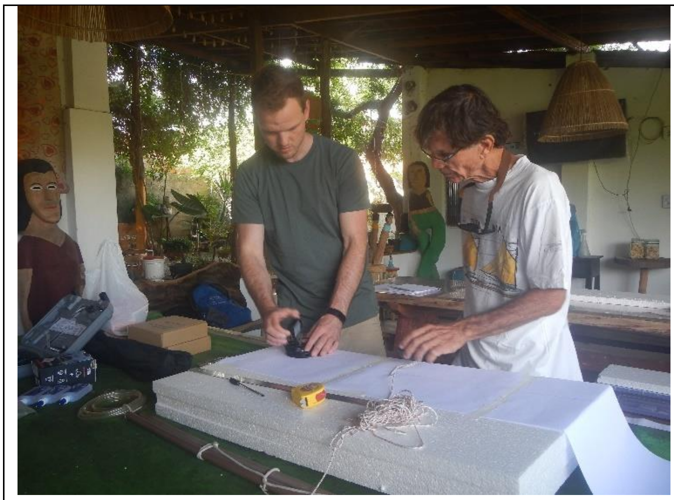

Figure 8 - Probe installation considerations

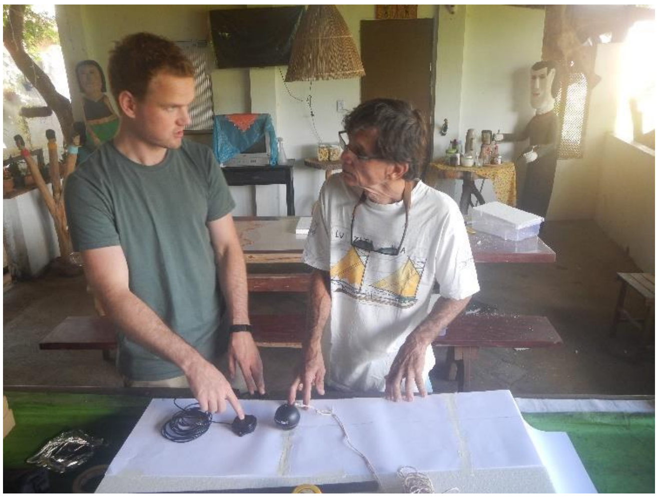

Figure 9 - Idem

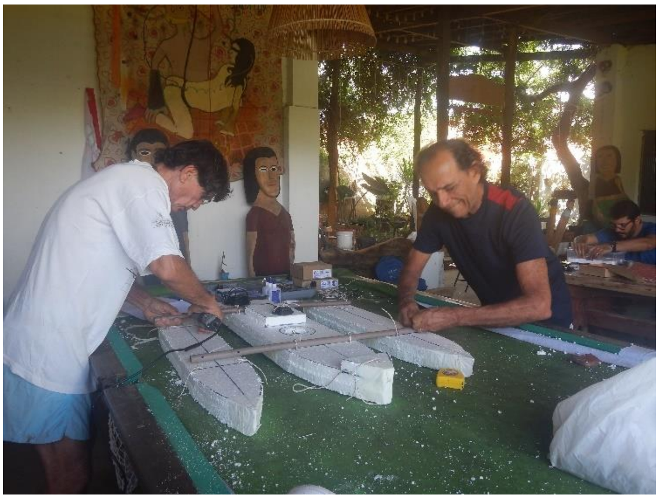

Figure 10 – Assembling the prototype

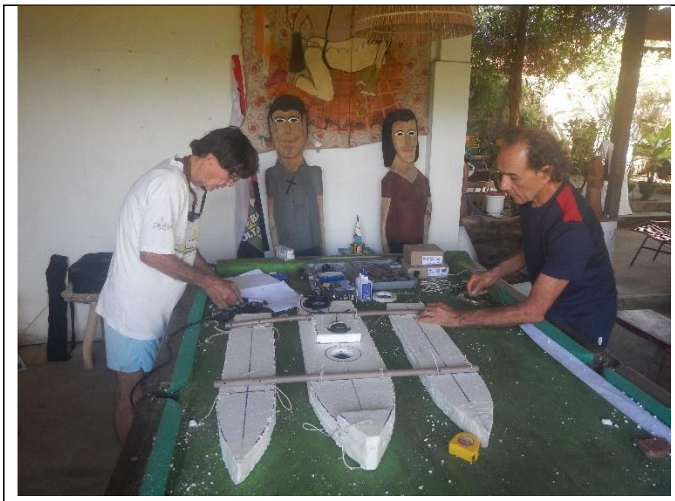

Figure 11 - Idem

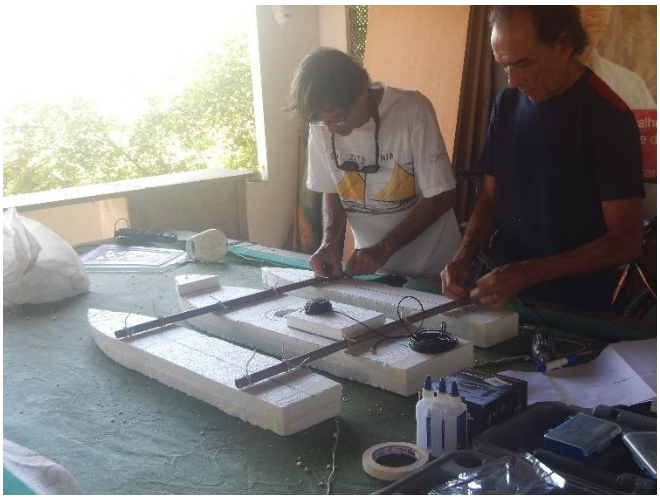

Figure 12 – Final assembling steps

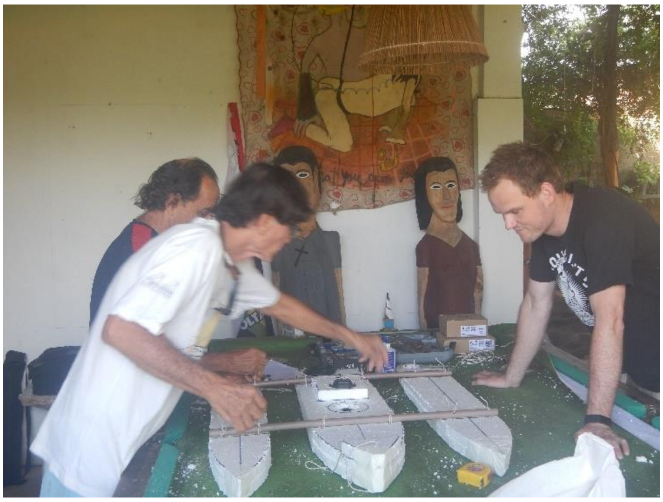

Figure 13 - Idem

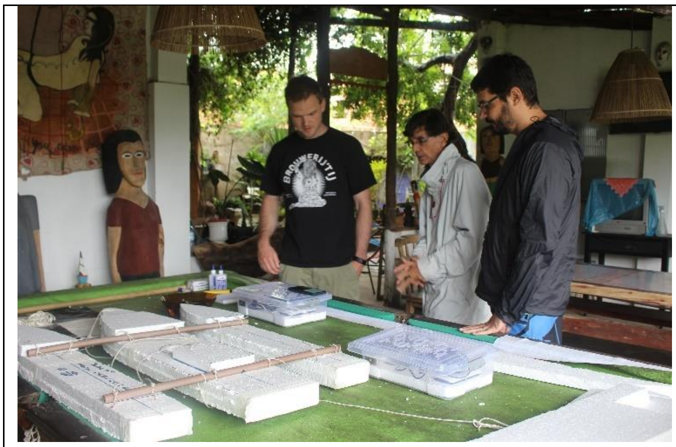

Figure 14 - Integration of systems with the trimaran

Figure 15 - Idem

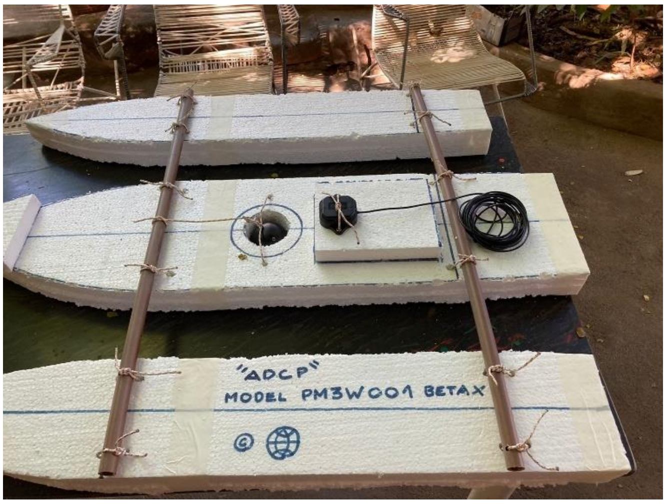

Figure 16 – Prototype ready to tests

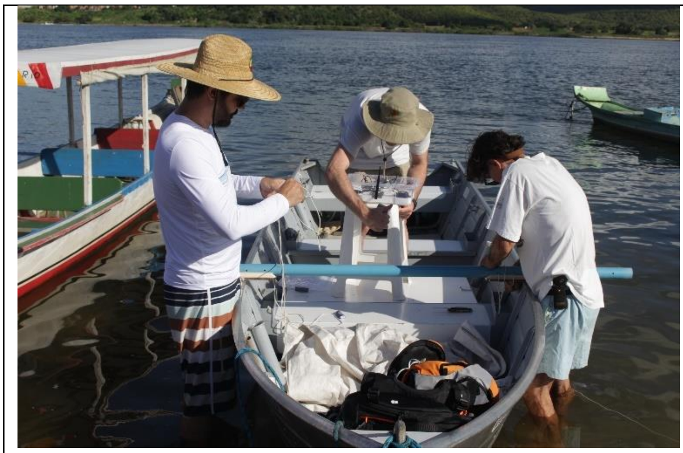

Figure 17 - Assembling the mother boat's frame

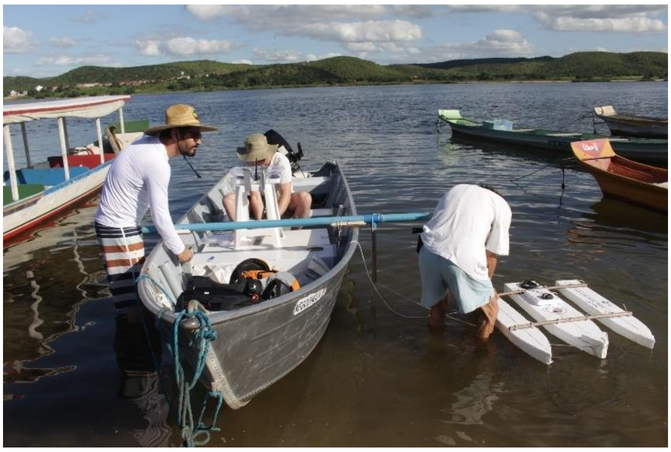

Figure 18 – Connecting the trimaran to the mother boat

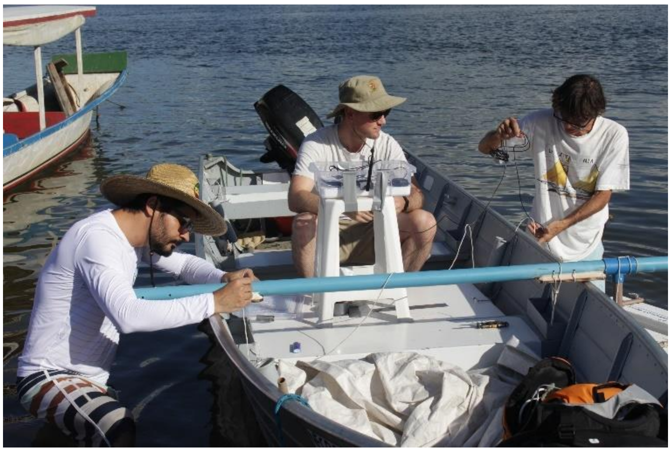

Figure 19 – Final adjustments

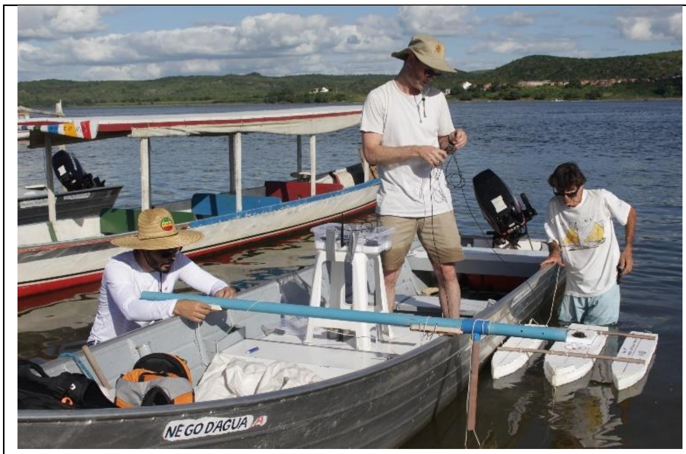

Figure 20 – Idem

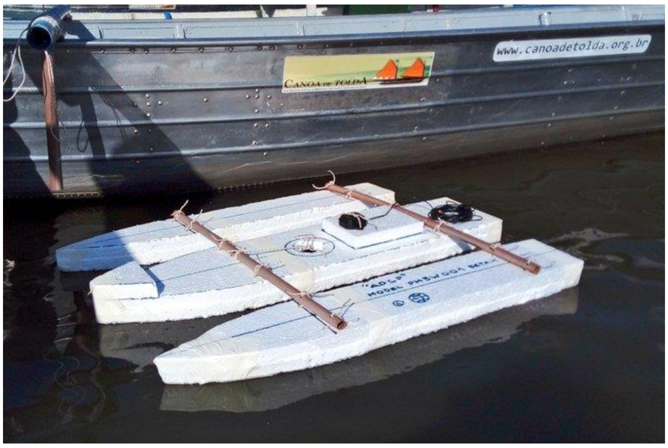

Figure 21 – Trimaran ready to sea trials

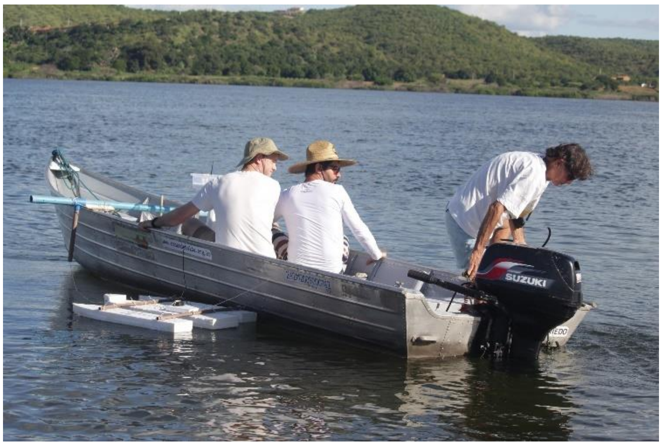

Figure 22 – Leaving to first trials

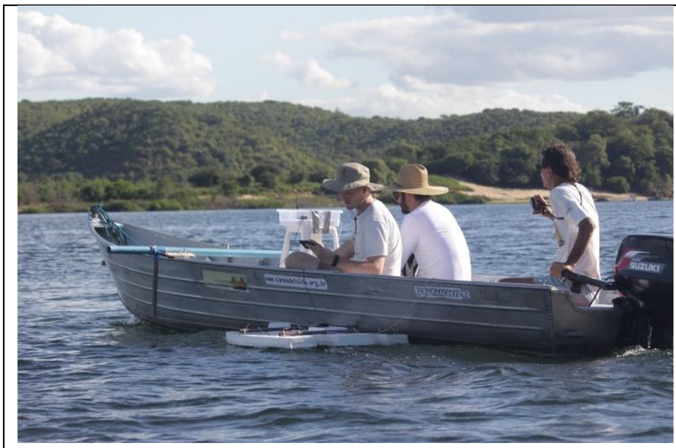
Figure 23 - Idem

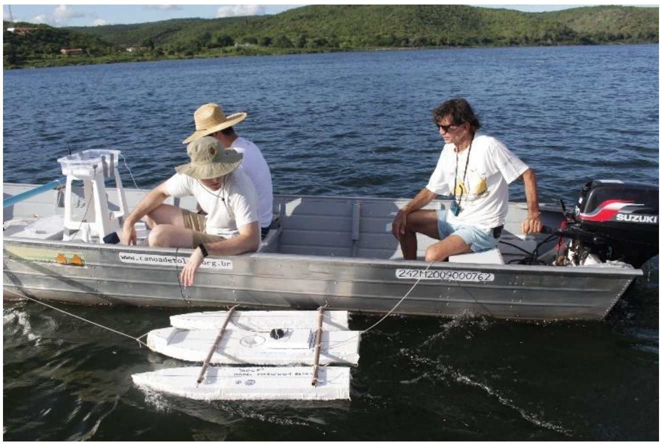
Figure 24 – On trials, trimaran behavior

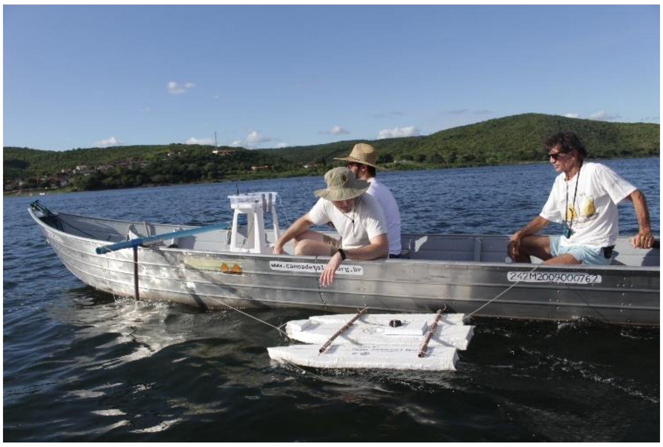
Figure 25 - Idem

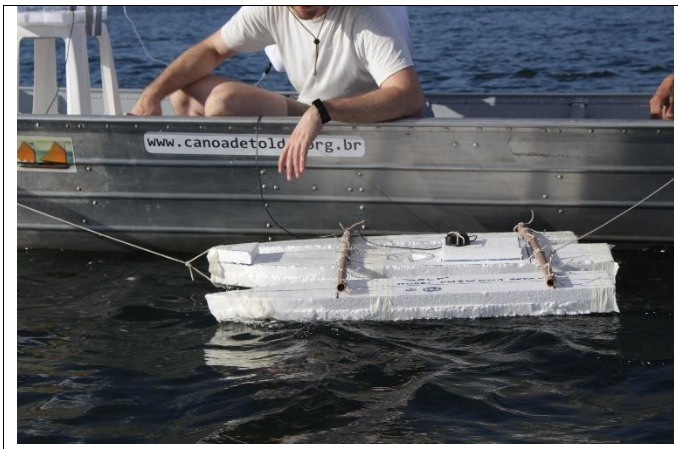

Figure 26 - Idem

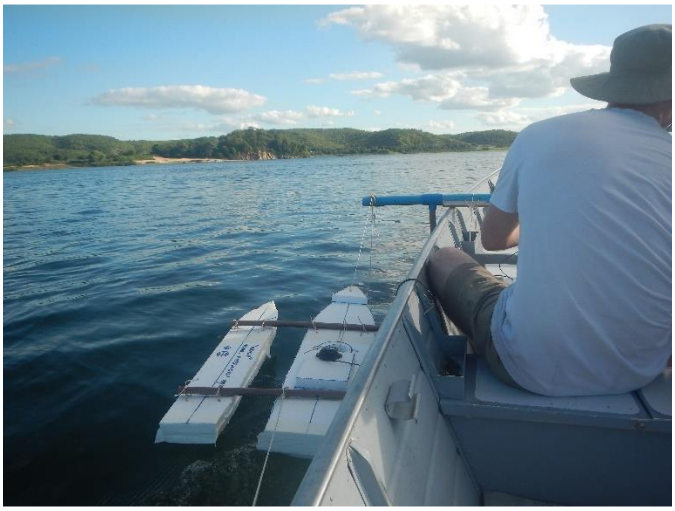

Figure 27 – Idem.

Figure 28 - Idem

Figure 29 – Idem

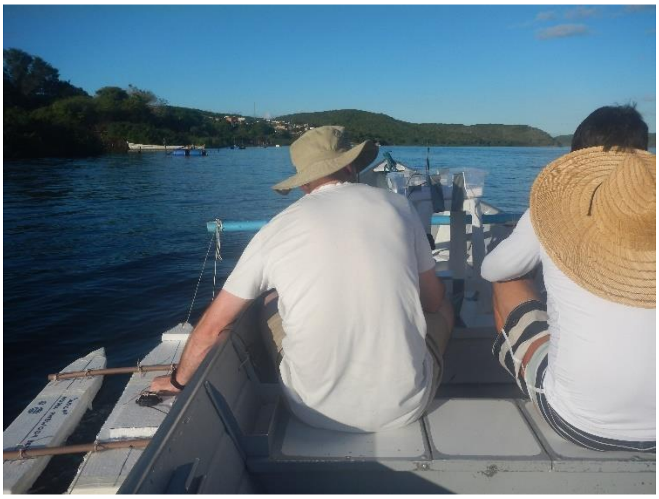

Figure 30 - Idem. Attention to GPS RTK instalation.

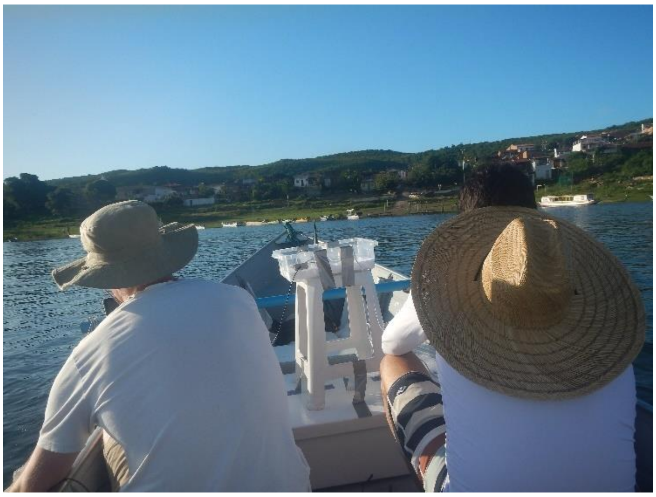

Figure 31 - GPS RTK rover onboard mother boat

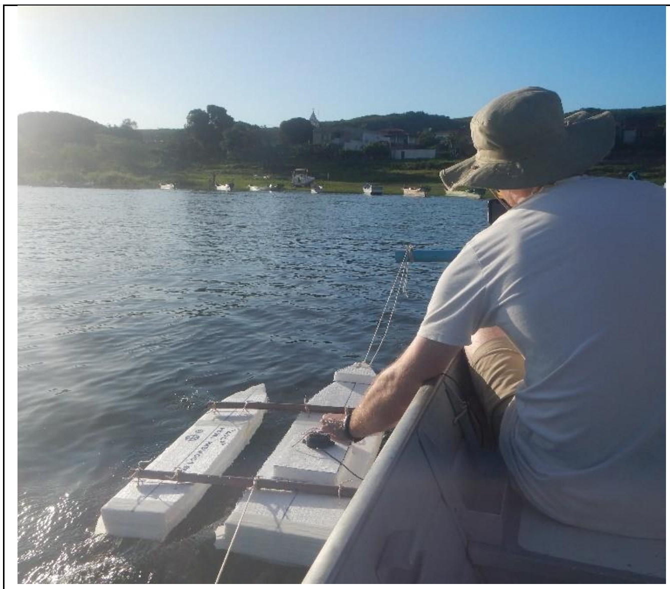

Figure 32 - GPS RTK antena on the trimaran

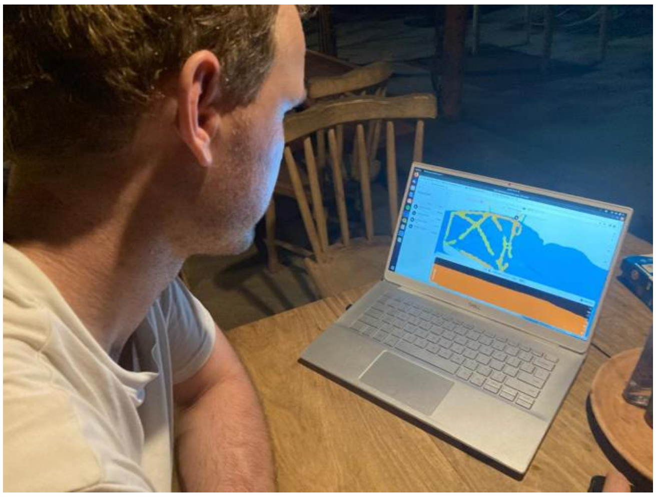

Figura 33 – Bathimetry results